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(54) Turbo-Compressor System for Fuel Cell Power Generation

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Specification

1. Title of the Invention

Turbo-Compressor System for Fuel Cell Power Generation

2. Scope of the Claims

(1) A turbo-compressor system for fuel cell power generation wherein a compressor is installed in the gas supply line connected to the entrance of the air electrode and the modifier in the fuel cell, a variable nozzle type turbine is installed in the exhaust gas line connected to the outlet of the air electrode and the modifier such that the compressor is operated by this turbine to supply almost constant air pressure characterized in that the outlet of the compressor and the entrance of the turbine are connected via a by-pass line; and a flow rate regulating valve is installed in this by-pass line so that it opens into an operational area with a lower amount of air supplied to the fuel cell and the modifier.

(2) A turbo-compressor system for fuel cell power generation wherein a compressor is installed in the gas supply line connected to the entrance of the air electrode and the modifier in the fuel cell, a variable nozzle type turbine is installed in the exhaust gas line connected to the outlet of the air electrode and the modifier such that the compressor is operated by this turbine to provide almost constant air pressure supplied; characterized in that the outlet of the compressor and the entrance of the turbine are connected via a by-pass line; a flow rate regulating valve is installed in this by-pass line so that it opens into an operational area with a lower amount of air supplied to the fuel cell and the modifier; and a precalciner is installed in order to give thermal energy to the air passing through the bypass-line.

3. Detailed Description of the Invention

(A) Industrial Field of Application

The present invention relates to a turbo-compressor system incorporated in the fuel cell power generation system.

(B) Prior Art

A fuel cell power generation system can achieve higher thermal efficiency compared to a conventional steam power generation system using petroleum and coal as fuel sources, and has better flexibility in terms of location. For this reason, recently a variety of uses have been investigated, including commercial electric power sources installed in buildings as well as power sources for special uses such as space development, and fuel cell power generation has been developed actively aiming at its practical applications.

A fuel cell power generation system comprises a fuel cell having an electrolyte layer between an air electrode and a hydrogen electrode, a modifier for supplying hydrogen gas serving as a fuel to said hydrogen electrode by modifying hydrocarbon fuels such as natural gas, and an air feeding means for supplying air into said air electrode and said modifier. The performance of said fuel cell tends to improve along with an increase in the reactive gases pressures. For this reason, the operational pressures of said reactive gases are limited to values of about 3 to 6 kg/cm^2 g. In this case, a large power source is required for compression of air and its value reaches approximately 20% of the energy generated from the cell. On the other hand, modification reactions for generating fuel gases of the cell are carried out at a high temperature of approximately 800°C so that exhaust gases at high temperatures are

exhausted from said modifier. Therefore, if the power for compressing air can be supplied from the exhaust gas energy of the system, it has a great effect on the improvement of system efficiency.

Under this circumstance, in the recent fuel cell power generation system, a turbo-compressor as an air supplying means has been generally installed. That is, a turbo-compressor is designed to be driven in the following manner. A compressor is installed in the gas supply line that is connected to the entrance of the air electrode and the modifier in the fuel cell as well as installing a turbine in the gas exhaust line that is connected to the outlet of the air electrode and the modifier. The compressor is operated by this turbine such that the supply air pressure is maintained to be almost constant. As a result, the energy from the exhaust gases is recovered by the turbine to be utilized in the work of compressing air in an attempt to improve the system efficiency.

A relatively small-scale fuel cell power generation system installed privately in individual buildings has a characteristic feature in that the power demands greatly change in a specific time zone such as the lunchtime break. For this reason, there is a request that the amount of air supplied to the fuel cell and the modifier can be changed in a broad range from approximately 25% to 100%. In contrast, from the aspect of performance of the cell and from the aspect of control over the fuel cell system, there is a request that the air pressure supplied to the fuel cell should be maintained at a relatively high constant value. Therefore, if a regular turbo compressor is simply applied for compressing air in the fuel cell, there is a limitation in its characteristics so that the aforementioned requests cannot be satisfied. In the turbo-compressor used in this system, it is necessary to control the ejection pressure of the compressor to always indicate almost a constant value by using a variable rate type nozzle in the turbine. If the flow rate is reduced while maintaining the constant ejection pressure for the compressor, the compressor may cause surging and operation may become unstable. In an extreme case, the compressor may be damaged. That is, if the preset ejection pressure is high, the operational conditions of the compressor may easily enter the surging generation area A indicated by the oblique lines in Fig. 1 in the area showing a lower flow rate so that it becomes difficult to manage a normal air compression action. For this reason, it is difficult to change the air flow rate to be supplied into the fuel cell in a broad range from 25% to 100% by using the aforementioned conventional system.

(C) Purposes

The present invention aimed at this situation and the object of the present invention is to provide a turbo-compressor system for fuel cell power generation wherein the ejection pressure is maintained at a constant value and the supply air flow rate to the compressor is also controlled freely over a broad range without having problems such as surging. Therefore, the turbo-compressor system for fuel cell power generation can be employed favorably in the fuel cell power generation system used under conditions where power demands change in a broad range.

(D) Constitution

According to the present invention, in order to achieve the aforementioned object, the turbo-compressor system for fuel cell power generation comprises a compressor in the gas supply line connected to the entrance of the fuel cell's air electrode and the modifier, and also a variable rate nozzle type turbine in the gas exhaust line connected to the outlet of the air electrode and the modifier such that the compressor is operated using this turbine for the supply air pressure to be almost constant. The system is characterized in that the outlet of the compressor and the entrance of the turbine are connected via a by-pass line, and a flow rate regulating valve is installed in this by-pass line

wherein the valve opens in the area of operation when the amount of air supplied to the fuel cell and the modifier is small, or a flow rate regulating valve and a precalciner are installed.

(E) Embodiments

Embodiments of the present invention are explained specifically below with reference to the drawings.

Embodiment 1 (Fig. 2)

Fig. 2 shows a turbo-compressor system for fuel cell power generation according to the present invention. 1 is a fuel cell, 2 is a modifier and 3 is a turbo-compressor. The fuel cell 1, as shown schematically in the drawing, comprises a hydrogen electrode 6 forming a hydrogen chamber 5 on one side of the porous electrode 4, an air electrode 9 forming an air chamber 8 on one side of the porous electrode 7 and an electrolyte 11 between the hydrogen electrode and the air electrode. Power generation is carried out by consecutively supplying hydrogen gas as a fuel to the hydrogen chamber 5 and also by supplying compressed air into the air chamber 8. Further, the modifier 2 generates hydrogen gas by modifying hydrocarbon fuel such as natural gas to consecutively supply hydrogen gas to the hydrogen electrode 6 of the fuel cell 1. The fuel and the compressed gas are introduced from an inlet 2a and high temperature exhaust gases are discharged from an outlet 2b. In a turbo-compressor 3, a compressor 12 is operated by a turbine 14 having a variable nozzle 13. The compressor 12 is installed in the middle of the gas supply line 15 where the beginning terminal is opened to the atmosphere and the end terminal is connected to the entrance 8a of the air chamber 8 of the fuel cell and the entrance 2a of the modifier 2. The turbine 14 is installed in the middle of the exhaust gas line 16 where the beginning terminal is connected to the outlet 8b of the air chamber 8 and the outlet 2b of the modifier 2 and the end terminal is opened to the atmosphere. Further, the outlet of the compressor 12 and the entrance of the turbine 14 are connected via a by-pass line 17 and a flow rate regulating valve 18 is installed in this by-pass line 17. This flow rate regulating valve 18 is designed to open in the operational area wherein the amount of air supplied to the fuel cell 1 and the modifier 2 is less. For example, its opening/closing is controlled by an actuator (not shown) operated based on the air flow rate flowing in the gas supply line 15 and the rotary speed of the turbo-compressor as input signals.

Now, 20 and 21 are flow rate regulating valves for regulating the air supply amount to the fuel cell 1 and to the modifier 2.

According to this constitution, the turbine 14 is operated by excess air at the outlet of the air electrode of the fuel cell 1 and the exhaust gas from the modifier 2, such that the compressor 12 is operated. Consequently, air passing through the gas supply line 15 is compressed to a specified pressure, and subsequently supplied to the air chamber 8 and the modifier 2 in the fuel cell 1 to carry out power generation. In this system, the amount of air supplied to the fuel cell 1 and the modifier 2 can be controlled, for example in a range from approximately 25% to 100%, while keeping the pressure of the compressed air ejected from the compressor 12 constant by regulating the opening of the variable nozzle 13 of the turbine 14, thus coping with the changes in power demands in a broad range. As for its controls, if the operational conditions of the compressor 12 enter the surging generation area A as shown in Fig. 1, the flow rate regulating valve 18 is opened appropriately. As a result, a part of the air ejected from the compressor is introduced to the turbine side via the by-pass line 17. For this reason, the flow rate of air passing through the compressor 12 increases so that the operational conditions of the compressor 12 are returned to the

normal operational area B at the right side from the surge line 1. As a result, generation of surging is prevented effectively. Therefore, this system can cope with the changes in power demands in a broad range without any problems, such as unstable operation and damaging of the compressor.

Embodiment 2 (Fig. 3)

In the same system as in said Embodiment 1 (the same symbols are used for the same or corresponding areas to omit explanation) a precalciner 22 is installed in the middle of the by-pass line 17. The precalciner 22 is designed so that the fuel consecutively supplied from the outside is combusted in order to add thermal energy to the air passing through the by-pass line 17.

According to this constitution, in addition to the fact that the same effects as in Embodiment 1 are obtained, the advantage is that the insufficient output of the turbine 14 can be compensated for by the precalciner 2, thus securing stable operation. That is, when the temperature elevation modification is not as fast as the increases in power demands and the turbine power is temporarily insufficient, or when the turbine power is always insufficient in a certain operational area in terms of the characteristics of the turbo-compressor, the insufficient power can be compensated for by adding thermal energy to the air passing through the by-pass line while supplying fuel to said precalciner 22 as well as maintaining proper operation over the operational area in a broad range.

In this case, it is natural that the means for opening and closing the flow rate regulating valve in the by-pass line is not limited by those listed above. Various modifications can be made in a range not deviating from the object of the present invention.

(F) Effects

According to the constitution of the present invention, a turbo-compressor system for fuel cell power generation can be provided wherein ejection pressure is maintained at a constant value and the amount of air supplied to the compressor is controlled freely in a broad range without causing any problems such as surging, and therefore the turbo-compressor system for fuel cell power generation can be used favorably in the fuel cell power generation system that is used under such conditions where power demands change in a broad range.

4. Brief Description of the Drawing

Fig. 1 is a characteristics explanatory diagram showing the characteristics of a compressor. Fig. 2 is a system explanatory diagram showing an embodiment of the present invention. Fig. 3 is also a system explanatory diagram showing another embodiment of the present invention.

1: Fuel cell

2: Modifier

3: Turbo-compressor

9: Air electrode

12: Compressor

13: Variable rate nozzle

14: Turbine

17: By-pass line

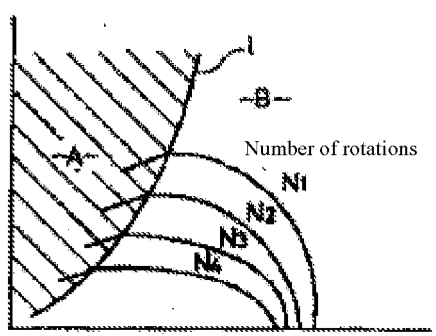
18: Flow rate regulating valve

22: Precalciner

Agent: Kazuhiro Akazawa, Patent Attorney

Fig. 1

Compression ratio
of the compressor
(or ejection pressure)



Flow rate of the compressor

N_1, N_2, N_3, N_4: Number of rotations

Fig. 2

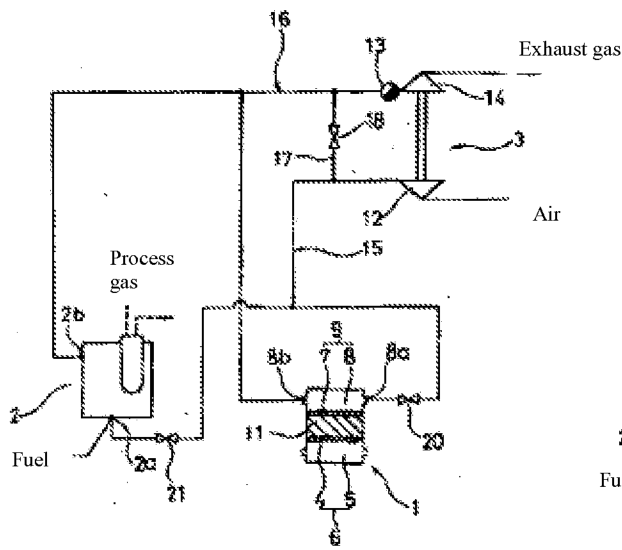
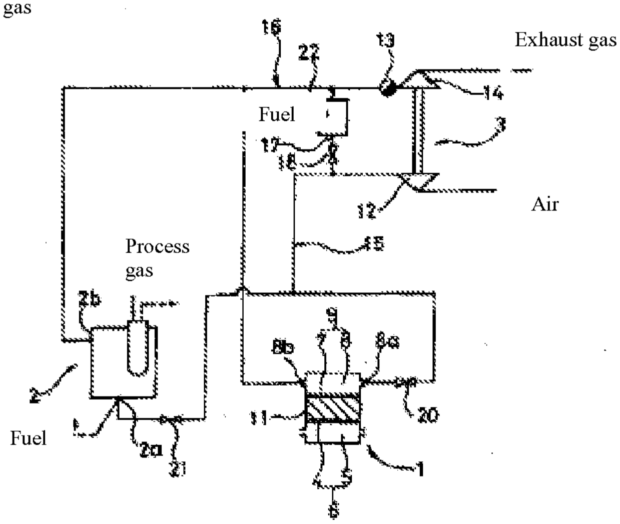

16
13
Exhaust gas
14
18
3
17
12
Air
Process
gas
15
2b
9
8b
7
8
8a
2
11
20
Fuel
2a
21
4
5
1
6

Fig. 3


16
22
13
Exhaust gas
14
Fuel
3
17
18
12
Air
Process
gas
15
2b
9
7
8
8b
8a
2
11
20
Fuel
2a
21
4
5
1
6